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VEGETATION OF THE KOKSILAH MARSH, COWICHAN ESTUARY: A PRE-RESTORATION STUDY, JULY 1985

Neil K. Dawe
Lindsay E. Jones

TECHNICAL REPORT SERIES No. 9
Pacific and Yukon Region 1986
Canadian Wildlife Service

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Vegetation of the Koksilah Marsh, Cowichan estuary: a pre-restoration study, July 1985

Neil K. Dawe
Lindsay E. Jones[1]

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Abstract

To determine the effect of returning a former agricultural field (Koksilah Marsh) and adjacent disturbed wetland (CN Marsh) on the Cowichan River estuary to intertidal habitat, baseline vegetation and soil-water salinity data were gathered in July and September 1985.

Three permanent transects were established across the areas of proposed impact and from a total of 103 releves, 21 species of vascular plants were recorded. Seven additional species from the family Gramineae were also noted. Four plant communities were identified and are described along with elevation and soil water salinity data. Broad predictions of the resulting vegetation, following a return of the study area to tidal inundation, are made.

Résumé

Durand les mois de juillet et septembre 1985, des données sur la végétation et sur la salinité de l'eau et du sol ont été receuillies afin de déterminer l'effet qu'un retour à l'influence des marées aura sur un champ agricole (le marécage Koksilah) et sur la marécage adjacent (le marecage CN) qui sont situés dans l'estuaire de la rivière Cowichan.

Trois transects permanents furent établis dans la zone affectée et un total de 21 espèces de plantes vasculaires furent denombrées dans les 103 places échantillonnees. Aussi, sept espèces de gramines furent notées. Quatre communautees de plantes furent identifiees et sont décrites tout en incorporant les données sur l'élévation et la salinite de l'eau du sol. Des prédictions générales concernant le type de végétation qui s'établira suite a l'èffet des marées sont présentées.

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Introduction

The Cowichan estuary (see Fig. 1) has long been recognized as important migratory bird and fish habitat. Thirty-one species of fish have been found in the estuary and adjacent waters, and at least 229 species of birds use the estuary throughout the year (Cowichan Estuary Task Force 1980).

Competition by man for use of the estuarine habitat has also been great. Since dyking activities began in the late 1800's, over 50% of the intertidal zone has been developed for agricultural or industrial use. Most of the native high marsh communities on the estuary have been eliminated. That, and the persistent and extensive log storage in the lower intertidal zone with its attendant dredging and filling activities have been significant impacts to waterfowl habitat on the estuary (Cowichan Estuary Task Force 1980).

One result of the wildlife vs. industrial use conflict was the implementation of an environmental management plan (Lambertsen 1984). The goal of that plan was to achieve balanced resource use in the Cowichan estuary by limiting further agricultural encroachment, by reducing industrial use, and by using appropriate wildlife management techniques to return alienated land to estuarine habitat. Proposed rehabilitation sites were designated habitat management areas. Even after implementation of the management plan, however, over 45% of the 490 ha of estuarine habitat will have been lost.

As a result of the concern for that loss, a number of government and non-government agencies have been active in reserving, protecting and restoring key areas of wildlife habitat within the estuary. Recently, 17.4 ha of dyked agricultural land, hereafter referred to as the Koksilah Marsh, were acquired by The Nature Trust. That provided an opportunity to return intertidal circulation to the area and restore the property to its former value as intertidal marsh habitat. Coincidentally, the area lies adjacent to the CN Marsh, a designated habitat management area on the estuary (Lambertsen 1984).

To complement a Restoration Concepts Plan for the Koksilah Marsh by the cooperating agencies (see Appendix 1), we conducted a study to gather existing vegetation data from the site and the adjacent CN Marsh that would serve as a baseline from which comparisons could be made once restoration activities had begun. This paper reports on that study.

Location and Description of Study Area

The study site is located on the south-central portion of the Cowichan estuary (Fig. 1). It is bounded on the north and east by a causeway and on the south and west by the Koksilah River. The Koksilah Marsh had, for many years, been used to grow hay crops. The adjacent CN Marsh had been a combination of marsh and upland habitat for a number of years before 1982. In December of that year, a winter storm breached the seaward dyke. Subsequently the Koksilah Marsh/CN Marsh setback dyke also failed at one point (Lambertsen 1984). As a result of those breaches, high-salinity waters inundated the CN Marsh and reached the lower elevations of the Koksilah Marsh. The setback dyke was repaired, but small amounts of salt water still get through. The breach in the sea dyke was not repaired.

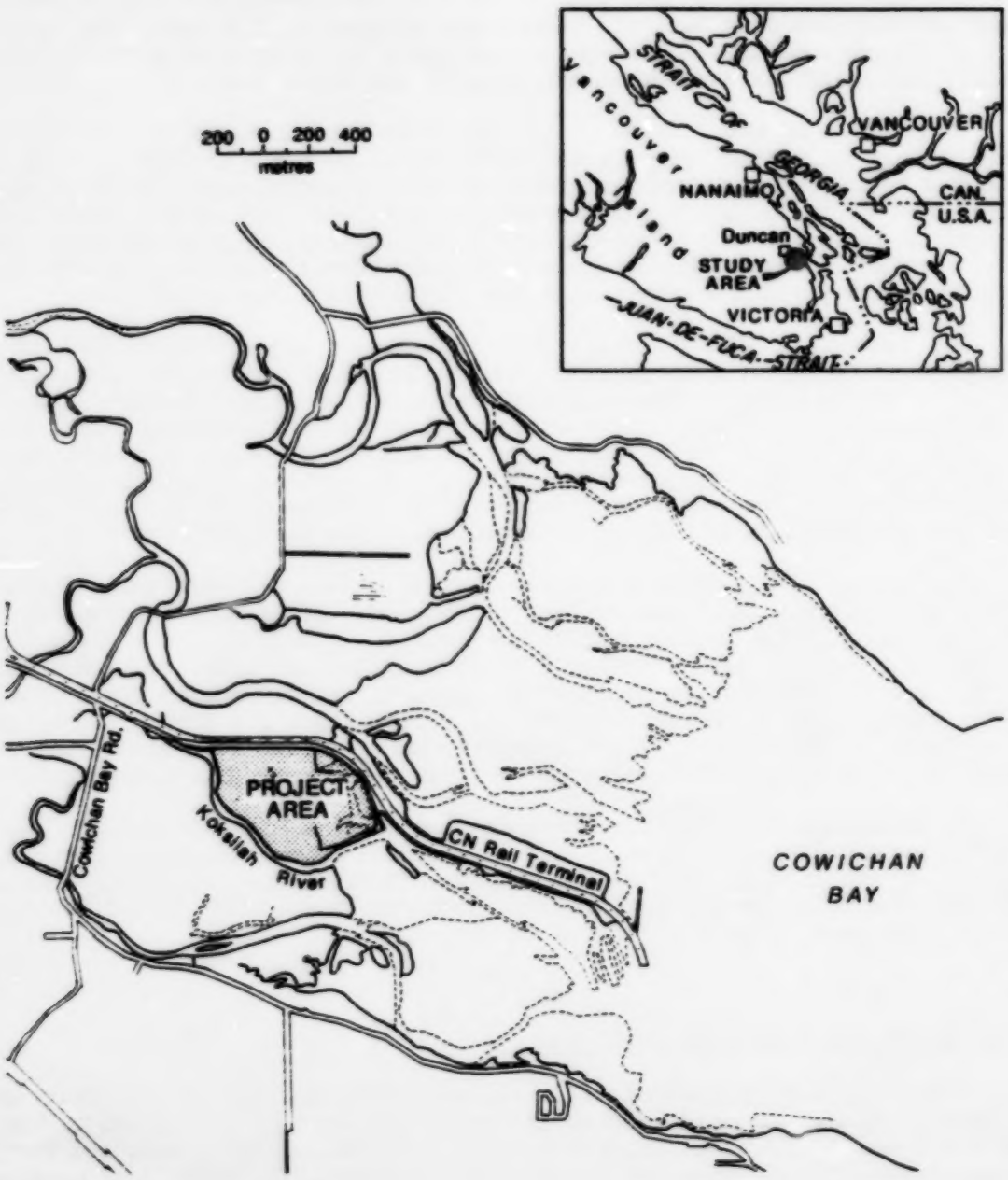

FIGURE 1 Location of the Koksilah Marsh Study Area, Cowichan River Estuary.

Methods

On 4 July 1985, we established three transects across the study area: two on the Koksilah Marsh and one on the CN Marsh (Appendix 2). The transects were oriented to pass through all the herbaceous vascular plant communities visually distinguishable within the study area. At 5m intervals along the transect all vascular plant species within a $1m^2$ releve were identified and recorded. Nomenclature follows that of Hitchcock and Cronquist (1973). The relative cover of each species was recorded using the Braun-Blanquet cover/abundance scale (Mueller-Dombois and Ellenberg 1974). Because the Koksilah Marsh fields had been mowed to remove a hay crop just before the study, most species of the family Gramineae could not be identified and so were lumped collectively under "grasses". Occasionally, when a grass could be identified to species, it was noted and a species list was compiled for future comparisons. The amount of unvegetated soil within each releve was also recorded. Substrate elevation data were taken at the centre of each releve based on the nearest geodetic benchmark. For comparison, four releves were established adjacent to the study area on a small intertidal island in the Koksilah River channel (Appendix 2). Similar data were taken at those releves.

Data were analysed using the reciprocal averaging multivariate technique described by Orloci (1978). That method has a dual purpose: a single application results in the ordination of both releves and species in terms of best fit of one to the other. Species with similar site distribution and sites with similar species composition are related independent of species abundance or site richness (Pimintel 1979). Analysis was carried out using the computer program RQT (Orloci 1978). Species with frequencies <10% were excluded from analysis. Frequency of occurrence was calculated by summing the number of occurrences of a species within a dataset and dividing that by the number of possible occurrences within the dataset. Best estimates of mean cover/abundance for each species were calculated by summing the midpoint of each Braun-Blanquet scale range (i.e. by setting r=.01, +=.05, 1=3, 2=15, 3=37.5, 4=67.5, and 5=87.5) and dividing by the number of occurrences of the species within the dataset. Species and releve scores were plotted on scatter diagrams. Product moment correlations of the first three releve ordination axes with elevation were calculated.

Tidal inundation ratios were calculated using the 1983 predicted tides for Fulford Harbour. Those predicted tides were converted to local chart datum based on differences between Fulford Harbour tides and those of the secondary port at Cowichan. The year 1983 was chosen for the prediction set as it represents an approximately average year in the 18.6 year tidal cycle (Fred Stephenson, personal communication). Geodetic elevations were converted to chart datum (ACD) by adding to them the mean water level at Cowichan Bay taken from 1985 tide tables (Anonymous 1985). Those chart datum elevations were considered to have an error of $\pm$0.06m (F. Stephenson, personal communication).

Soil water salinity data were gathered from the study area on 10 September 1985. Samples were taken by squeezing a drop of water from a small soil sample onto an American Optical hand refractometer and reading the value directly.

Results

From 103 releves a total of 21 species of vascular plants was recorded from the study area (Appendix 3). An additional seven species of grasses were identified from the hayed portion of the Koksilah Marsh fields (Appendix 4). Of the 21 species and combined hayfield grasses, only seven had both cover/abundance and frequency values of 10% or more (Table 1). Four of those species are tolerant of high salinities: Spergularia canadensis, Atriplex patula, Salicornia virginica, and Cotula coronopifolia. Cover/abundance data for all releves are shown in Appendix 5.

Canonical correlations for the first three sets of species and releves scores are high (Appendix 6) suggesting that the reliability of the scores as ordering criteria is also high (Orloci 1978). The first three canonical variates accounted for 79% of the total Chi-square (Appendix 6). Species scores were plotted on a scatter diagram (Fig. 2) to show their relationships with one another and to assist in interpreting the scatter diagram of the releve scores (Fig. 3). The releves were separated along the first two axes of the ordination into two major divisions. The first division (Canonical axis I) contrasts releves having species characteristic of undisturbed soils (High and Low Meadows) with those having species indicative of disturbed (saltwater inundated) soils (Disturbed Meadow, Disturbed Marsh). The second division (Canonical axis II) separated releves within the two groups mentioned above on an elevational gradient into four major vegetation groups which we have called communities: High and Low Meadows, Disturbed Meadow and Disturbed Marsh. Product moment correlations of releve elevations with the first three sets of releve scores were highest for Canonical axis II ($p<0.001$; Appendix 7). Canonical axis II could then be interpreted as increasing in elevation from 0 to 1. Mean cover/abundance and frequency of occurrence values of species within the four communities are shown in Table 2. The locations of the four communities are shown in Appendix 2. Releve elevations are shown in Appendix 8. Mean elevations and predicted inundation periods for each group can be found in Table 3. Soilwater and standing water salinity values are given in Table 4; sample locations are shown in Appendix 2.

The two meadow communities separated on an elevational gradient. Trifolium repens and Taraxacum officinale were the differential species, found only in the High Meadow. The Disturbed Meadow had a species composition similar to the Disturbed Marsh. Salicornia virginica was not found within releves of the Disturbed Meadow although occasional small clumps of that species were subsequently noted there. The Disturbed Meadow occurred at the lowest elevations on the study site where it followed the remnant dentritic channels. Occasionally, interspersed along the sides of the main channel were bands of dead Scirpus maritimus. The Disturbed Meadow had large areas of unvegetated soil. Soil water salinities were extremely high in those unvegetated sites; in fact three of the sample readings exceeded the refractometer scale (>160‰). Some areas with Spergularia canadensis or Atriplex patula growth had soil water salinity values that exceeded the salt tolerance levels reported for those species (Chapman 1960 p298). Soil water salinity values decreased as elevation increased. So too did soil moisture. As a result we could not squeeze enough water from the High or Low Meadow communities to obtain refractometer readings, although they must have been low judging from their species composition. The Disturbed Marsh mean elevations

Table 1. Vascular plant species mean cover abundance (%) and frequency of occurrence (%) for Koksilah Marsh and CN Marsh transects combined. See Appendix 3 for key to species names.

Data for releve 1 to releve 103

	Species	Mean cover/abun	Frequency
1	HAYD GRAS[1]	70.5	63
2	UNVE SOIL[2]	53.83	41
3	SPER CANA	16.6	37
4	ATRI PATU	17.36	31
5	TRIF REPN	23.63	23
6	TARA OFFI	13.45	20
7	COTU CORO	10.7	17
8	SALI VIRG	11.85	12
9	TRIF PRAT	1.5	4
10	DIST SPIC	11.2	4
11	SCIR MARI	.9	4
12	RUMX ACET	1.33	2
13	ALOP GENI	.5	2
14	RUMX SPEC	.5	1
15	RANU SPEC	.01	1
16	PLAN LANC	.5	-[3]
17	PUCC NUTK	15	-
18	CIRS ARVE	.5	-
19	UNKN COMP	.5	-
20	POTE PACI	.5	-
21	JUNC BUFO	.5	-
22	TRIG MARI	.01	-
23	PLAN MARI	.01	-

Total number of releves = 103

1 Includes a variety of agricultural grasses some of which appear in Appendix 4.

2 Unvegetated soil, while not a vascular plant species, is a dominant cover type and has been included for future comparisons.

3 Less than 1%.

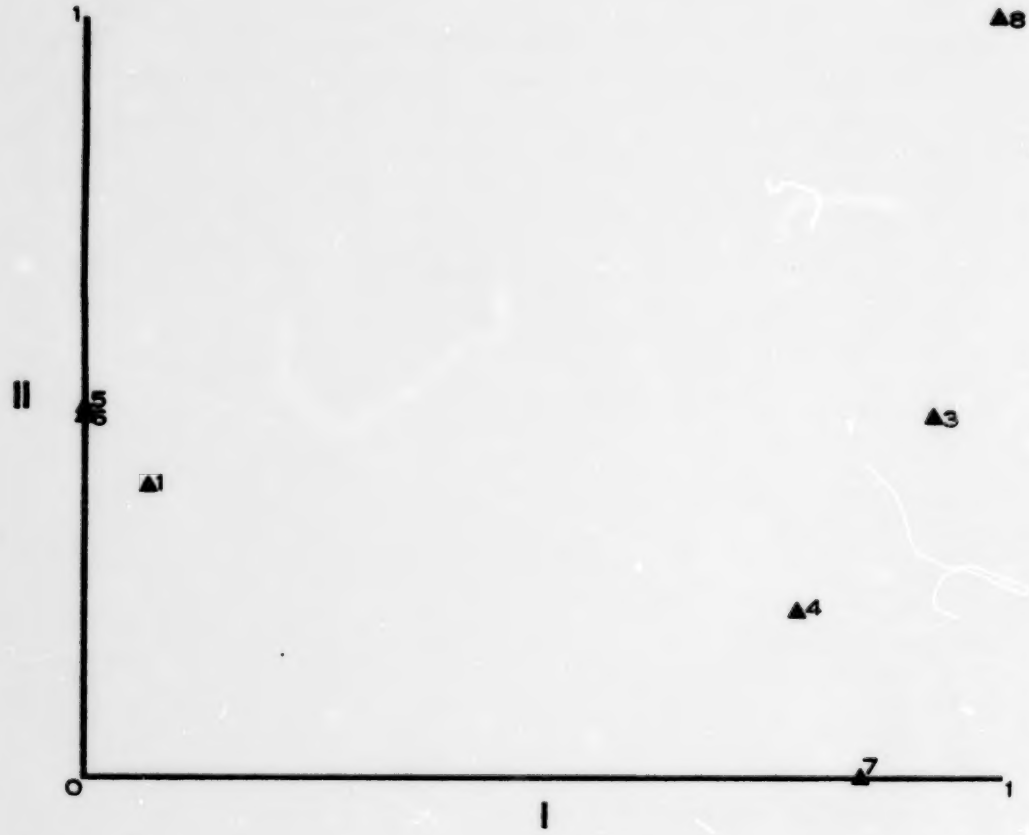

Figure 2. Scatter diagram of species scores for the first two canonical variates, Koksilah Marsh and CN Marsh, Cowichan River estuary. Numbers refer to species in Table 1 and Appendix 3.

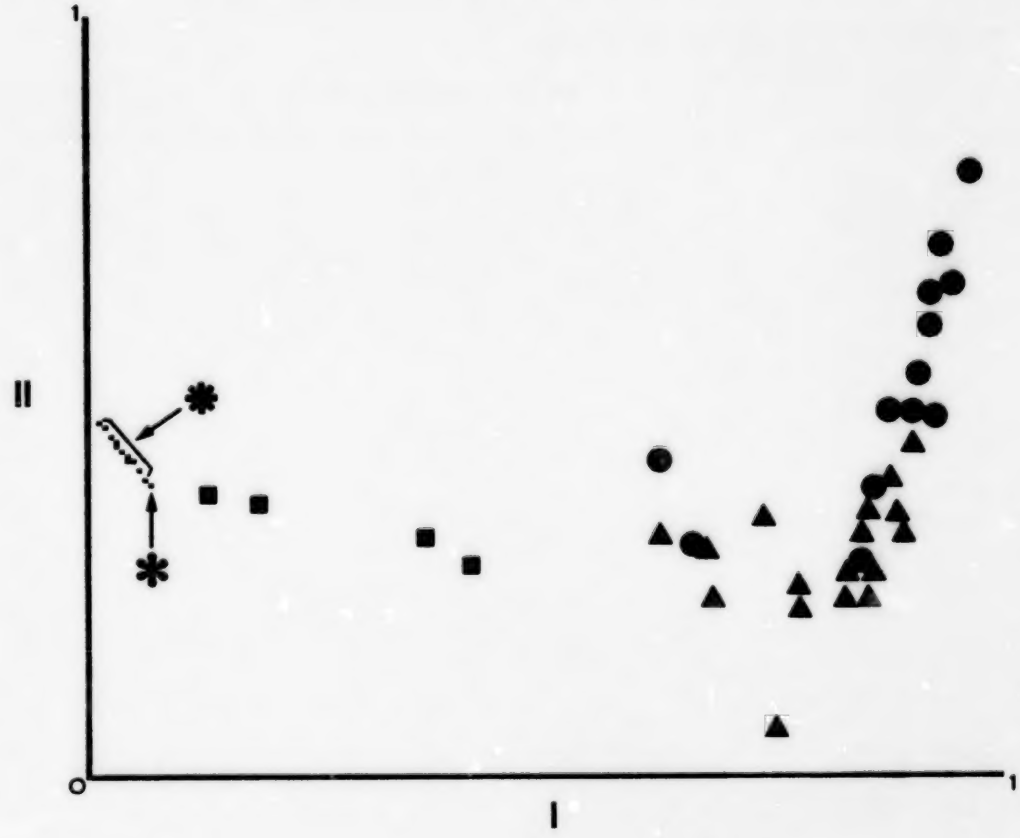

Figure 3. Scatter diagram of releve scores for the first two canonical variates, Koksilah Marsh and CN Marsh, Cowichan River estuary. ✱ = High Meadow, ✱ = Low Meadow, ▲ = Disturbed Meadow, ● = Disturbed Marsh, ■ = transitional releves.

Table 2. Vegetation communities of the Koksilah Marsh and CN Marsh with constituent species, their cover/abundance (%) and their frequency of occurrence (%). See Appendix 2 for key to species names.

Disturbed Meadow community

	Species	Mean cover/abun	Frequency
1	HAYD GRAS	15.56	28
2	UNVE SOIL	54.33	85
3	SPER CANA	17.57	75
4	ATRI PATU	23.16	57
5	TRIF REPN	0	0
6	TARA OFFI	0	0
7	COTU CORO	11.97	57
8	SALI VIRG	0	0
9	TRIF PRAT	0	0
10	DIST SPIC	13.5	10
11	SCIR MARI	.9	17
12	RUMX ACET	0	0
13	ALOP GENI	.5	10
14	RUMX SPEC	0	0
15	RANU SPEC	0	0
16	PLAN LANC	0	0
17	PUCC NUTK	0	0
18	CIRS ARVE	0	0
19	UNKN COMP	0	0
20	POTE PACI	.5	3
21	JUNC BUFO	.5	3
22	TRIG MARI	.01	3
23	PLAN MARI	0	0

Total number of releves - 28

Table 2. (continued)

Low Meadow community

	Species	Mean cover/abun	Frequency
1	HAYD GRAS	86.69	100
2	UNVE SOIL	3	3
3	SPER CANA	0	0
4	ATRI PATU	11	12
5	TRIF REPN	0	0
6	TARA OFFI	0	0
7	COTU CORO	0	0
8	SALI VIRG	0	0
9	TRIF PRAT	0	0
10	DIST SPIC	0	0
11	SCIR MARI	0	0
12	RUMX ACET	1.33	9
13	ALOP GENI	0	0
14	RUMX SPEC	.5	3
15	RANU SPEC	0	0
16	PLAN LANC	0	0
17	PUCC NUTK	0	0
18	CIRS ARVE	0	0
19	UNKN COMP	.5	3
20	POTE PACI	0	0
21	JUNC BUFO	0	0
22	TRIG MARI	0	0
23	PLAN MARI	0	0

Total number of releves - 31

Table 2. (continued)

Disturbed Marsh community

	Species	Mean cover/abun	Frequency
1	HAYD GRAS	9	11
2	UNVE SOIL	55.97	100
3	SPER CANA	15.47	100
4	ATRI PATU	11.75	66
5	TRIF REPN	0	0
6	TARA OFFI	0	0
7	COTU CORO	.5	11
8	SALI VIRG	11.85	72
9	TRIF PRAT	0	0
10	DIST SPIC	7.75	11
11	SCIR MARI	0	0
12	RUMX ACET	0	0
13	ALOP GENI	0	0
14	RUMX SPEC	0	0
15	RANU SPEC	0	0
16	PLAN LANC	0	0
17	PUCC NUTK	15	5
18	CIRS ARVE	0	0
19	UNKN COMP	0	0
20	POTE PACI	0	0
21	JUNC BUFO	0	0
22	TRIG MARI	0	0
23	PLAN MARI	.01	5

Total number of releves = 18

Table 2. (continued)

High Meadow community

	Species	Mean cover/abun	Frequency
1	HAYD GRAS	73.02	100
2	UNVE SOIL	0	0
3	SPER CANA	0	0
4	ATRI PATU	0	0
5	TRIF REPN	23.63	100
6	TARA OFFI	13.45	87
7	COTU CORO	0	0
8	SALI VIRG	0	0
9	TRIF PRAT	1.5	20
10	DIST SPIC	0	0
11	SCIR MARI	0	0
12	RUMX ACET	0	0
13	ALOP GENI	0	0
14	RUMX SPEC	.5	4
15	RANU SPEC	.01	8
16	PLAN LANC	.5	4
17	PUCC NUTK	0	0
18	CIRS ARVE	.5	4
19	UNKN COMP	0	0
20	POTE PACI	0	0
21	JUNC BUFO	0	0
22	TRIG MARI	0	0
23	PLAN MARI	0	0

Total number of releves = 24

Table 3. Geodetic and chart datum elevations with predicted inundation periods for vegetation communities of the Koksilah Marsh and CN Marsh, Cowichan River estuary. (Sample size is in parenthesis; R( ) = Range geodetic.)

Community		Mean Elevation (m) Geodetic	Above chart Datum	Inundation (%) Total day	Daylight hours
Disturbed Meadow R(0.46 to 0.69)	(28)	0.62	3.00	25.3	14.5
Low Meadow R(0.68 to 0.86)	(31)	0.75	3.13	17.6	10.3
Disturbed Marsh R(0.65 to 0.86)	(18)	0.91	3.29	9.3	5.7
High Meadow R(0.72 to 1.11)	(24)	0.93	3.31	8.1	5.1

Table 4. Soil water and standing water salinities for the Koksilah Marsh and CN Marsh, Cowichan River estuary, 10 September 1985.

Type	Salinity (‰)	Location
Koksilah Marsh		
Channel water	31	8
	31	10
	32	12a
Shallow standing water	40	4
	34	5
	37	7
	34	9
Unvegetated soil-water	160	1a
	160	1
	95	2
	52	3
	160	13
Spergularia soil-water	34	11a
	66	12b
	93	14
Atriplex soil water	100	6
	64	11c
	73	12c
Agrostis/*Atriplex* soil water	58	11b
	50	12d
Scirpus maritimus soil water	41	15
CN Marsh		
Channel water	32	17
	30	19
	29	21
Spergularia, *Salicornia*, *Atriplex* soil water	45	16
	35	18
Unvegetated soil	34	20
Estuarine water (outside dyke)	28	22

were the second highest on the study site. Vegetation had started to recover following the dyke breach, however we only found vegetation growth at the higher elevations of the marsh platform. Soil water salinities there were generally lower than those found within the distrurbed meadow. Vegetation data from releves taken on an island in the Koksilah channel are shown in Table 5.

Table 5. Species composition, mean cover/abundance (%), and frequency of occurrence (%) of vegetation on an island in the Koksilah River channel, Cowichan River estuary, at a mean elevation of 0.905m geodetic (3.28m ACD; n=4).

Species	Mean cover/abun	Frequency
Carex lyngbyei	29.5	100
Distichlis spicata	15.0	100
Glaux maritima	8.4	100
Agrostis sp.	28.5	75
Triglochin maritimum	26.0	50
Juncus sp.	67.5	25
Deschampsia cespitosa	15.0	25
Stellaria humifusa	15.0	25
Spergularia canadensis	3.0	25
Cotula coronopifolia	3.0	25

Discussion

As a result of the breaching of the sea dyke in 1982, the CN Marsh has undergone a dramatic change in vegetation. Kennedy (1982) described the area qualitatively from fieldwork completed in 1976. She identified three plant communities within the marsh, naming them according to the dominant vegetation. The community with the greatest areal extent was the Carex/Distichlis community. It was composed primarily of species indicative of brackish to saline conditions. The elevational range of the community was about 0.0 m to 0.5 m geodetic (2.4 m to 2.9 m ACD). The second largest community, the Barbarea/Holcus community, was primarily composed of species intolerant of saline conditions and typical of upland sites. The community ranged from about 0.5 to 1.0 m geodetic (2.9 m to 3.4 m ACD).

Following the initial dyking of the CN Marsh, rainwater would likely have reduced the salt concentrations at the higher elevations allowing a shift to the typically upland grasses, herbs, and shrubs of the Barbarea/Holcus community. The lower elevations, however, must still have been exposed to salts, although at reduced levels. It appears that some salt water was percolating through the dyke allowing the Carex/Distichlis community to be maintained. Over time even the vegetation of the lower elevations would likely become accustomed to reduced salinities (A. Ceska, personal communication). When the dyke was breached in 1982 nearly all the vegetation within the marsh was killed, likely from the additional stress of the high

salinity inundating water and accompanying inundation periods. Wayne (personal communication) conducted a brief survey of the marsh in July 1983 and found only minor amounts of Distichlis spicata, Triglochin maritimum, Atriplex patula, and Hordeum sp. alive. Today the marsh appears to be slowly recovering following a similar successional pattern to that of the Englishman River estuary after dyke removal there (Dawe and McIntosh, in prep.).

Following the breach in the sea dyke of the CN Marsh and the subsequent breach in the setback dyke, salt water gained access to the Koksilah Marsh. Even after the latter dyke had been repaired and a culvert with a one way flap gate was installed, salt water intrusion still occurred. During the summer months, salt water trapped at the lower elevations on the Koksilah Marsh would evaporate concentrating the salts. That is suggested by the extremely high soil water salinities we found there, which appear to be limiting vegetative growth on large areas within the community. In the CN Marsh, soil water salinity from an area with no vegetation was less than that of vegetated areas. Therefore, it appears vegetation in the CN Marsh is being affected more by elevation of the substrate and the resultant inundation ratio than by salinities, as is the case with the disturbed meadow community. Once tidal inundation has been returned to the Koksilah Marsh, tidal flushing should reduce those high salinities to acceptable levels for plant growth. In a San Francisco Bay study it took less than six months to reduce, through tidal flushing, the salinity of salt evaporation ponds to acceptable levels for plant colonization (Josselyn and Perez 1981).

There are a number of factors that will interact to determine the resulting plant communities following a return of the Koksilah Marsh to an intertidal regime. Major factors in the distribution of vascular plant species within brackish and salt marshes include salinity of the inundating water, elevation of the substrate, and texture of the soil (Dawe and White 1982, Dawe and White 1986). Preliminary results suggest that inundating water salinities will be in the order of 25°/oo or greater during the summer period of low flows from the Koksilah and Cowichan Rivers. Based on other studies at the Nanoose-Bonell (Dawe and White 1986) and the Englishman estuaries (Dawe and McIntosh, in prep.), and the elevation, salinity, and vegetation composition data of the releves we sampled in the Koksilah channel, we would expect the vegetation of the Koksilah Marsh and the CN Marsh to shift to predominately halophytic vegetation likely dominated by Distichlis spicata. Elevation of the site and the resultant inundation periods suggest communities similar to the Distichlis/Salicornia flats or perhaps the somewhat higher Distichlis/Deschampsia flats communities at Nanoose-Bonell (Dawe and White 1986). The lower elevations, particularly along the remnant channel edges will possibly return to a Scirpus maritimus or Carex lyngbyei channel community. Although we know of no freshwater influence other than the rivers, the Cowichan estuary is rich in exceptionally productive aquifers (Cowichan Estuary Task Force 1980). Any additional freshwater source on the study site could affect the final composition of the vegetation there.

The baseline information provided here will allow comparisons to be made with data gathered following the return of tidal inundation to the study site. The resulting information will enable researchers to predict with more accuracy future habitat work of this type on the Cowichan estuary and other coastal sites. Therefore we recommend that, once tidal inundation has been returned to the study site, a monitoring program of the vegetation be instigated and continued annually for at least a five year period.

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APPENDICES

Appendix 1

Koksilah Marsh Restoration Project
cooperating agencies:

Ministry of Environment
Fisheries and Oceans, Canada
Canadian Wildlife Service
Nature Trust of British Columbia
Ducks Unlimited Canada
Cowichan Estuary Preservation Society

Appendix 2

Map of the Koksilah Marsh and CN Marsh study sites, Cowichan River estuary, showing locations of the plant communities, transects and releves, and the soil water salinity data collection sites. (Map in back pocket.)

Appendix 3

Vascular plant species compiled from all releves within the Koksilah Marsh and CN Marsh study sites, Cowichan River estuary, July 1985.

	Acronym	Species
1	HAYD GRAS	*Graminae* species
2	UNVE SOIL	Unvegetated soil
3	SPER CANA	*Spergularia canadensis*
4	ATRI PATU	*Atriplex patula*
5	TRIF REPN	*Trifolium repens*
6	TARA OFFI	*Taraxacum officinale*
7	COTU CORO	*Cotula coronopifolia*
8	SALI VIRG	*Salicornia virginica*
9	TRIF PRAT	*Trifolium pratense*
10	DIST SPIC	*Distichlis spicata*
11	SCIR MARI	*Scirpus maritimus*
12	RUMX ACET	*Rumex acetosella*
13	ALOP GENI	*Alopecurus geniculata*
14	RUMX SPEC	*Rumex* species
15	RANU SPEC	*Ranunculus* species
16	PLAN LANC	*Plantago lanceolata*
17	PUCC NUTK	*Puccinellia nutkaensis*
18	CIRS ARVE	*Cirsium arvensis*
19	UNKN COMP	Unknown Compositae
20	POTE PACI	*Potentilla pacifica*
21	JUNC BUFO	*Juncus bufonius*
22	TRIG MARI	*Triglochin maritimum*
23	PLAN MARI	*Plantago maritima*

Appendix 4

Grass species observed on the meadow communities of the Koksilah Marsh study site, Cowichan River estuary, July 1985.

Agropyron repens
Agrostis sp.
Dactylis glomerata
Holcus lanatus
Lolium perenne
Phalaris arundinaceae
Poa sp.

Appendix 5

Vegetation data gathered at the Koksilah Marsh and CN Marsh, Cowichan River estuary, July 1985. See Appendix 3 for key to species.

KOKSILAH/CN MARSH VEGETATION DATA (1985) - PAGE 1

RELEVE NUMBER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1 HAYD GRAS	5	5	5	4	3	5	2	3	4	5	3	4	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
2 UNVE SOIL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 SPER CANA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 ATRI PATU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 TRIF REPN	3	2	1	3	3	2	5	5	3	3	2	2	3	1	+	+	1	+	3	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 TARA OFFI	1	2	2	2	2	1	2	2	2	2	3	3	2	1	2	2	2	2	+	R	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 ODTU CORO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 SALI VIRG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9 TRIF PRAT	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 DIST SPIC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 SCIR MARI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12 RUMX ACET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 ALOP GENI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 RUMX SPEC	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
15 RANU SPEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 PLAN LANC	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 PUCC MUTK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18 CIRS ARVE	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 UNKN COMP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20 POTE PACI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 JUNC BUFO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 TRIG MARI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 PLAN MARI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

KOKSILAH/CN MARSH VEGETATION DATA (1985) - PAGE 2

RELEVE NUMBER

	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
1 HAYD GRAS	5	5	5	5	5	5	R	0	+	0	0	0	1	0	5	5	5	5	5	5	5	5	5	5	2	2	0	0	0	0	0	0	0	0	0
2 UNVE SOIL	0	0	0	0	0	0	0	2	1	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	2	3	5	5	5	4	5	5	5	5
3 SPER CANA	0	0	0	0	0	0	0	3	2	0	0	1	3	3	0	0	0	0	0	0	0	0	0	0	3	2	3	1	1	2	3	0	0	1	0
4 ATRI PATU	0	0	0	0	0	0	5	2	2	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	2	3	+	0	0	0	0	0	0	0	0
5 TRIF REPN	0	0	1	1	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 TARA OFFI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 COTU CORO	0	0	0	0	0	0	0	2	2	0	0	0	1	+	0	0	0	0	0	0	0	0	0	0	2	+	R	+	0	0	0	0	0	+	0
8 SALI VIRG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9 TRIF PRAT	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 DIST SPIC	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11 SCIR MARI	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0
12 RUMX ACET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	1	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 ALOP GENI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0
14 RUMX SPEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 RANU SPEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 PLAN LANC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 PUCC NUTK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18 CIRS ARVE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 UNKN COMP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20 POTE PACI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 JUNC BUFO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 TRIG MARI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 PLAN MARI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

KOKSILAH/CN MARSH VEGETATION DATA (1985) - PAGE 3

RELEVE NUMBER

	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
1 HAYD GRAS	0	0	0	0	0	0	0	1	4	5	5	5	+	5	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0
2 UNVE SOIL	5	5	5	3	3	3	3	2	1	0	0	0	1	0	5	5	3	5	3	2	2	3	5	4	5	4	3	5	3	2	3	5	5
3 SPER CANA	+	0	0	2	2	3	2	+	0	0	0	0	0	+	1	1	2	1	3	1	4	1	1	2	1	2	2	2	3	2	2	2	1
4 ATRI PATU	0	0	0	1	3	+	3	4	3	1	1	+	1	2	+	0	1	0	1	3	1	3	0	2	1	1	0	1	1	0	2	2	0
5 TRIF REPH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 TARA OFFI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 COTU CORO	0	0	0	2	1	1	2	1	0	0	0	0	5	2	0	0	0	0	0	0	0	0	0	+	+	0	0	0	0	0	0	0	0
8 BALI VIRG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	+	1	1	2	0	+	+	0	2	3	0	+	3	0	1	+
9 TRIF PRAT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 DIST SPIC	0	0	R	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	2	0	0	0
11 SCIR MARI	0	0	0	0	+	0	0	0	0	0	0	0	R	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12 RUMX ACET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13 ALOP GENI	0	0	0	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 RUMX SPEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 RANU SPEC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16 PLAN LANC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 PUCC NUTK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
18 CIRS ARVE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 UNKN COMP	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20 POTE PACI	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 JUNC BUFO	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 TRIG MARI	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23 PLAN MARI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 6

Canonical correlations for the sets of species scores and releve scores and total Chi-square accounted for by canonical variates for the Koksilah Marsh and CN Marsh, Cowichan River estuary.

CANONICAL CORRELATIONS

SET 1 R(X,Y) = .94342882
SET 2 R(X,Y) = .649806331
SET 3 R(X,Y) = .581776648
SET 4 R(X,Y) = .454563133
SET 5 R(X,Y) = .427512883
SET 6 R(X,Y) = .245053326

TOTAL CHI-SQUARE ACCOUNTED
FOR BY CANONICAL VARIATES (%)

E(1) = 42.3793149 E CUMUL = 42.3793149
E(2) = 20.1050003 E CUMUL = 62.4843152
E(3) = 16.1156852 E CUMUL = 78.6000005
E(4) = 9.83840339 E CUMUL = 88.4384038
E(5) = 8.70231138 E CUMUL = 97.1407152
E(6) = 2.85928475 E CUMUL = 100

Appendix 7

Product moment correlation coefficients of releve elevations with the first three sets of releve scores, Koksilah Marsh and CN Marsh, Cowichan River estuary (N=96).

$r_1 = -.285536$ ($P<.005$)

$r_2 = .408186$ ($P<0.001$)

$r_3 = -.301413$ ($P<0.005$)

Appendix 8

Elevation data (m geodetic) of releve centres from Koksilah Marsh and CN Marsh, study area, Cowichan River estuary, July 1985.

Transect 1

Releve	Elevation	Releve	Elevation	Releve	Elevation
1	1.04	25	0.70	49	0.66
2	1.06	26	0.70	50	0.80
3	1.02	27	0.69	51	0.83
4	1.07	28	0.71	52	0.86
5	1.09	29	0.72	53	0.86
6	1.11	30	0.73	54	0.79
7	1.10	31	0.73	55	0.79
8	1.03	32	0.76	56	0.79
9	1.03	33	0.73	57	0.79
10	1.03	34	0.73	58	0.76
11	0.98	35	0.78	59	0.73
12	0.93	36	0.74	60	0.69
13	0.91	37	0.77	61	0.66
14	0.90	38	0.83	62	0.63
15	0.85	39	0.78	63	0.59
16	0.88	40	0.72	64	0.61
17	0.88	41	0.73	65	0.62
18	0.82	42	0.60	66	0.59
19	0.81	43	0.61	67	0.60
20	0.73	44	0.61	68	0.62
21	0.73	45	Channel	69	0.55
22	0.74	46	Channel	70	0.55
23	0.72	47	0.46	71	0.51
24	0.68	48	0.65	72	0.55
				73	Not taken

Appendix 8. (continued)

Transect 2

Releve	Elevation
74	0.60
75	0.68
76	0.66
77	0.66
78	0.66
79	0.69
80	0.71
81	0.69
82	0.70
83	0.66
84	0.67
85	0.56

Appendix 8. (continued)

Transect 3

Releve	Elevation
86	0.65
87	0.87
88	0.87
89	0.91
90	0.96
91	0.95
92	0.96
93	0.90
94	0.97
95	0.96
96	0.91
97	0.94
98	0.94
99	0.89
100	0.92
101	0.96
102	0.96
103	0.86

MAPS NOT

FILMED

CARTES

OMISES